

Available online at www.sciencedirect.com**ScienceDirect**

Procedia Engineering 90 (2014) 657 – 662

**Procedia
Engineering**www.elsevier.com/locate/procedia

10th International Conference on Mechanical Engineering, ICME 2013

Anaerobic digestion of kitchen waste to produce biogas

Salma A. Iqbal*, Shahinur Rahaman, Mizanur Rahman, Abu Yousuf

Department of Chemical Engineering & Polymer Science, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh

Abstract

Kitchen waste (KW) can be utilized to produce biogas due to its high biodegradability, calorific value and nutritive value to microbes, which will reduce our dependency on fossil fuels. The research work was conducted to investigate the production ability of biogas as an alternative energy from KW with co-digestion of cow manure (CM) through anaerobic digestion (AD). Firstly, three digesters were prepared to observe the individual degradation rate of KW, CM and co-digested KW with CM at room temperature (25°C~30° C) and at temperature of 37°C (mesophilic digestion) respectively and observed the degradation rate for co-digested KW with CM was higher than KW and CM alone. Secondly, three digesters were constructed to observe the effect of alkalinity at temperature 37° C and loading rate 200 gm/L. Three alkali (NaOH) doses 1.0%, 1.5% and 2.0% on wet matter basis of kitchen waste were applied to improve biodegradability and biogas production. The highest degradation rate was 6.8 ml/gm which was obtained from 1.5% NaOH and also observed that biogas production was almost doubled from treated KW than untreated KW. Finally, a portable biogas reactor was fabricated for pilot-scale biogas production which included an agitator and heating system. This reactor was operated at both 37° C and room temperature at a loading rate of 200 gm/L and observed that the digestion rate was faster at 37° C than room temperature. The prime object of this work was to investigate the prospect of kitchen waste for biogas production and ultimate protection of environment from the bad effect of methane gas that would be produced by uncontrolled anaerobic digestion.

© 2014 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license

[\(http://creativecommons.org/licenses/by-nc-nd/3.0/\)](http://creativecommons.org/licenses/by-nc-nd/3.0/).

Selection and peer-review under responsibility of the Department of Mechanical Engineering, Bangladesh University of Engineering and Technology (BUET)

Keywords: Anaerobic digestion; cow manure; kitchen waste; biogas

1. Introduction

Anaerobic digestion is a complex biological process in which microorganisms break down biodegradable organic

* Corresponding author. Tel.: +8801711951184; fax: +880-821-715257.

E-mail address: salmacep@gmail.com

matter i.e. cattle manure, kitchen waste, sewage sludge, poultry dropping, agriculture residues and other organic garbage in the absence of oxygen and thus produced biogas [1]. Bangladesh is an energy starved under developed country. At present the major energy production in Bangladesh is based on natural gas. Around 33% of the total population is covered by electricity network and 4% are covered under natural gas network. About 82% of total electricity comes from natural gas [2]. Since 2005, the increased gas demand outpaced gas supply resulting a gas shortage. As the demand is increasing and the reserve of the natural gas is decreasing, it is assumed that very early the supply of the nature gas will start to decline [3]. The continuous depletion of fossil fuel is sticking the concern into the search for new energy sources to be used. So we should focus our view on the alternative renewable energy sources such as solar energy, biogas, biodiesel, wind power, tidal energy etc. [4].

Almost 80% people of our country directly or indirectly depend on agriculture. During winter seasons, huge amounts of vegetables are cultivated and due to lack of efficient transportation and preservation, huge amounts of vegetables are wasted, which may be a source of biogas [5]. CM is used to produce biogas to generate electricity and heat. The gas is rich in methane and is used in rural areas of Bangladesh to provide a renewable and stable source of energy. Therefore, CM has limited availability in many areas particularly in urban area. Preparation of biogas from CM have been using mainly in rural areas but there is also plenty amount of biomass in urban area, which will be a potential source of biogas [6]. Moreover, production of biogas will reduce the use of fossil fuels, thereby reducing CO₂ and poisonous gas emission. This research work was conducted to utilize KW and CM and this paper demarcates briefly the prospect of KW for biogas production in Bangladesh. The aim of this paper was also investigate the effects of organic loading rate (OLR), temperature and treatment of KW with NaOH.

2. Materials and methods

2.1. Waste collection and processing

KW was collected from different halls of Shahjalal University of Science & Technology (SUST) and Surma residential area, Sylhet and kept in digesters to produce biogas through AD. CM was collected from nearby village. In kitchen waste, total amount of rotten vegetables and rotten rices were near about 70%. Potatoes, eggs, fruits etc. were relatively low in mass. After removing the bones, plastic bags, metals and inorganic residues, wastes were cut into small size in order to reduce size to get efficient biogas production [7]. Then these wastes were mashed into pest by using hopper.

2.2. Experimental set-up

A simple lab-scale experiment was fabricated using ten digesters. Each digester was made of glass. The volume of each digester was 1 L and working volume was 0.5 L. In this study the volume of produced gas was measured by water displacement method considering the volume of the generated gas equal to that of expelled water in the water collector. Each digester was connected to water chamber (plastic bottles) by a plastic pipe (gas pipe) which was used to pass the produced gas into water chamber. Another plastic pipe (water pipe) was used to take the displaced water from the water chamber to the water collector which was fitted air sealed by M-seal. Both the ends of the gas pipe were inserted just at the top of the digester and the water chamber. The water pipe was inserted just bottom of the water chamber and top of water collector. The set up is illustrated in figure 1.

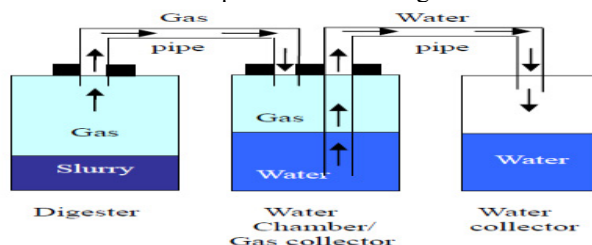


Fig.1. schematic diagram of the lab-scale experimental set-up (adapted from [5])

2.3. Lab scale experiment

Lab-scale experiments were operated in batch mode. Firstly, three digesters were prepared; D-1, D-2 and D-3 for KW, CM and co-digested KW with CM respectively. The digesters were run at room temperature and a temperature of 37°C (mesophilic digestion) respectively which was maintained by using water bath through pump. The substrate composition of the digesters is given in the table 1.

Table 1. Composition of batch digester at room temperature and a temperature of 37°C.

No. of digester(D)	Organic biomass KW(gm)	Bacteria seed CM(gm)
D-1	100	00
D-2	00	100
D-3	100	25

Further, four digesters were prepared (D-3.1, D-3.2, D-3.3 and D-3.4) by mixing KW and CM at different mixing ratio of 2:1, 4:1, 6:1 and 8:1 respectively. The amount of CM in all digesters was same. All digesters were kept into water bath to maintain optimum temperature (37°C). Retention time of 10-13 days was maintained for all feeding rate. The substrate composition of the digesters is given in the table 2.

Table 2. Feed stocks in digesters for co-digestion of kitchen waste with cow manure at 37°C for different loading rates.

No. of digester(D)	Mixing ratio of KW to CM	KW(gm)	CM(gm)	Loading rate (gm/L)
D-3.1	2:1	50	25	100
D-3.2	4:1	100	25	200
D-3.3	6:1	150	25	300
D-3.4	8:1	200	25	400

For the subsequent studies, another three digesters (D-4, D-5 & D-6) were set up to observe the effect of alkalinity at a loading rate of 200 gm/L. The mixing ratio of KW to CM was 4:1 in all digesters. The temperature was maintained at 37°C in all digesters. Three NaOH doses of 1.0%, 1.5% and 2.0 % on wet matter basis of KW were applied, where 1.0% was poured in D-4, 1.5% in D-5 and 2.0% in D-6. The feedstock is given in the table 3.

Table 3. Feed stock in batch digesters for NaOH-treated KW at temperature 37°C.

No. of digester(D)	Mixing ratio of KW to CM	KW(gm)	CM(gm)	NaOH (%)
D-4	4:1	80	20	1.0
D-5	4:1	80	20	1.5
D-6	4:1	80	20	2.0

2.4. Pilot scale experiment

After performing lab-scale experiments, one portable biogas reactor was fabricated for pilot-scale experiment which was made of plastic and volume of reactor was approximately 60 litres. According to the lab-scale experiment, the loading rate of 200 gm/L was carried out in reactor. An amount of 30 litres water, 6 Kg KW and 1.5 Kg CM were poured into the reactor. A metal agitator was placed from the top surface of the reactor. The agitator was agitated by manually for homogeneous mixing of biomass. To maintain optimum temperature (37°C) for mesophilic digestion, a heating spiral coil was placed inside the reactor and hot water from water bath was passed inside the reactor through pump. The reactor was operated in batch mode. The temperature was maintained for first 12 hours at 37°C and then next 12 hours was at room temperature and again 12 hours at 37°C and gradually so on. Figure 2 illustrates the schematic diagram of the pilot scale set up.

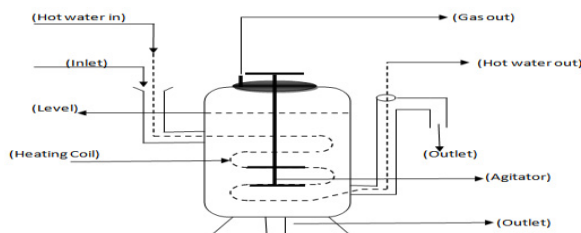


Fig. 2. a portable biogas digester set up

3. Results and discussions

3.1. Comparisons on biogas production from KW, CM and co-digested KW with CM at room temperature and a temperature of 37°C

Co-digestion is the simultaneous digestion of a homogenous mixture of two or more substrates. Results of co-digestion of kitchen waste and dairy manure in a two-phase digestion system conducted at laboratory scale showed that the gas production rate (GPR) of co-digestion was enhanced by 0.8 - 5.5 times as compared to the digestion with dairy manure alone [8]. In same loading rate and same temperature, the biogas production was investigated for digester D-1, D-2 and D-3. Comparisons on biogas production or degradation rate among KW, CM and co-digested KW with CM at room temperature and loading rate 200 gm/L were illustrated in figures 3 (a) and (b) respectively.

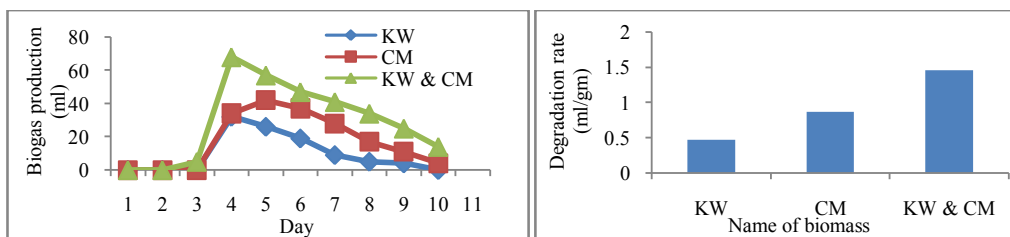


Fig. 3. (a) comparisons on biogas production (ml) at room temperature; (b) comparisons on degradation rate (ml/gm) at room temperature

Figure 3(a) shows that the digester D-3(co-digested KW and CM) produces more biogas than KW and CM alone. The degradation rates (ml/gm) for D-1, D-2 and D-3 digesters were 0.475 ml/gm, 0.865 ml/gm and 1.455 ml/gm respectively at room temperature. So the co-digestion of KW and CM would combine together the positive characteristics of the both feed stocks and could potentially brings better digestion performance and grow microorganism and gives more biogas.

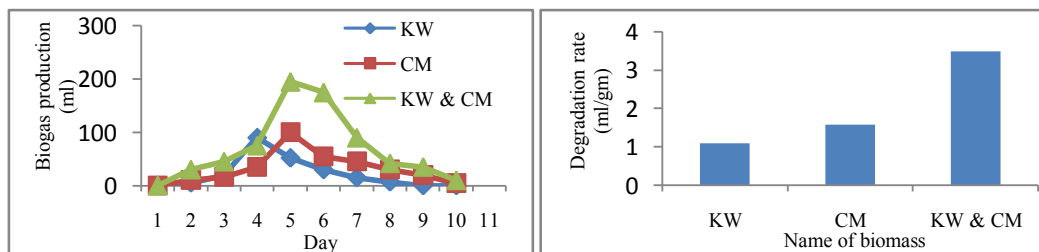


Fig. 4. (a) comparisons on biogas production (ml) at temperature of 37°C; (b) comparisons on degradation rate (ml/gm) at temperature of 37°C

The degradation rates (ml/gm) for D-1, D-2 and D-3 digesters were 1.095 ml/gm, 1.58 ml/gm and 3.485 ml/gm respectively at a temperature of 37°C. Figure 4(a) shows that the digester D-3(co-digested KW and CM) produces more biogas at temperature of 37°C (mesophilic digestion) than room temperature. So, among two experiments we

observed that the biogas production rate was higher at 37°C than room temperature and co-digestion of KW with CM gave more biogas production than KW and CM alone.

3.2. Effect of organic loading rate for co-digestion of KW with CM

One of the main objectives of this research was to determine the performance of the anaerobic digestion process, when operated at different loading rates. For this reason it was important to evaluate process performance in term of biogas production or degradation rates. To optimize the loading rate, digesters D-3.1, D-3.2, D-3.3 and D-3.4 were run at mesophilic condition (37°C) for co-digestion of kitchen waste with cow manure. Degradation rates during anaerobic process at different loading rates are shown in figure 5.

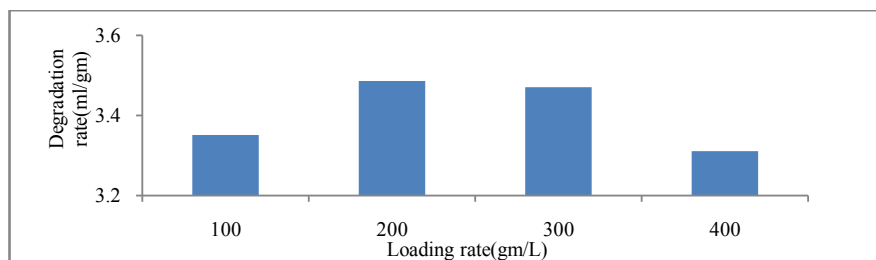


Fig. 5. degradation rate (ml/gm) for co-digestion of KW with CM at a temperature of 37°C for various loading rates.

Figure 5 represents the biogas production per gram of KW during the digesters operation at different loading rates. The degradation rates (ml/gm) for 100 gm/L, 200 gm/L, 300 gm/L and 400 gm/L loading rates were 3.35 ml/gm, 3.485 ml/gm, 3.47 ml/gm and 3.31 ml/gm respectively for co-digestion of kitchen waste with cow manure. The degradation rate of 200 gm/L was higher than other loading rates.

3.3. Effect of percentages of NaOH for co-digestion of KW with CM

Sodium hydroxide (NaOH) was added with KW in liquid state to improve biodegradability and biogas production. Three digesters (D-4, D-5 & D-6) were set up to observe the effect of alkalinity. The loading rate was same as 200 gm/L in all digesters. In same loading rate (200 gm/L) and at temperature of 37°C, the effects of percentages of NaOH for co-digestion of KW with CM were illustrated in figures 6(a) and (b) respectively.

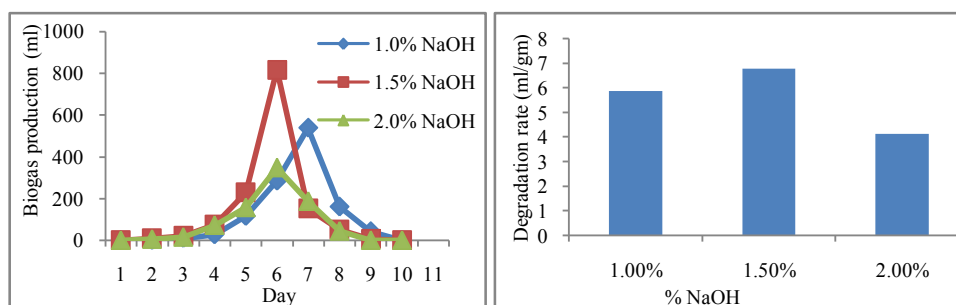


Fig. 6. (a) comparisons on biogas production (ml) at temperature of 37°C; (b) comparisons on degradation rate (ml/gm) at temperature of 37°C

From figures 6(a) and (b), it was detected that degradation rates (ml/gm) for 1.0%, 1.5% and 2.0% of NaOH doses were 5.88 ml/gm, 6.8 ml/gm and 4.14 ml/gm respectively for co-digestion of KW with CM. It was also found that the retention time for D-4, D-5 and D-6 digesters were 7, 8 and 7 days respectively. Although, retention time was longer for 1.5 % of NaOH but biogas production was higher than others. So, KW treated by 1.5% NaOH was optimum in this experiment.

3.4. Effect of temperature

Biogas production from organic substrates is strongly affected by the temperature where anaerobic digestion takes place. Generally at very low or high temperatures (e.g. temperatures below -10°C or above 90°C) microorganisms destroyed completely. So, it is essential to maintain optimum temperature (37°C) for biogas production. Comparisons on biogas production from digester D-3 and reactor at room temperature and at a temperature of 37°C are shown in figures 7(a) and (b) respectively. From figures 7(a) and (b), it was observed that the biogas production rate was higher at temperature of 37°C than room temperature.

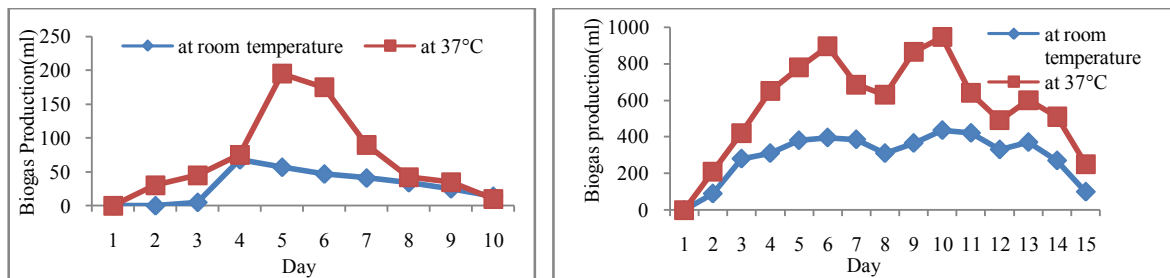


Fig. 7. (a) comparisons on biogas production at digester D-3; (b) comparisons on biogas production for pilot-scale experiment at reactor

4. Conclusion

Research and dissemination of biomass fuel throughout the country should be given priority in solving our energy crisis. Sustainable bio-energy development could reduce higher level of deforestation, net greenhouse gas emissions, and agricultural chemical runoff. Under mesophilic digestion (37°C) maximum biogas production was produced under the conditions- OLR 200 gm/L and KW treated with 1.5% NaOH. Finally, a portable biogas reactor was fabricated and it was working efficiently under the optimum conditions. The anaerobic co-digestion of kitchen waste with cow manure is demonstrated to be an attractive method for environmental protection and energy savings, but it is clear that with applying better equipment and adjustment of conditions more reasonable results can be obtained.

Acknowledgements

The research work was conducted in the water analysis laboratory of Chemical Engineering & Polymer Science (CEP) department, Shahjalal University of Science & Technology (SUST), Sylhet-3114, Bangladesh in 2013. The authors are grateful for the financial support of this research from Research Center, SUST and University Grants Commission (UGC), Bangladesh.

References

- [1] P. Milono, T. Lindajati, S. Aman, Biogas Production from Agricultural Organic Residues, The First ASEAN Seminar Workshop on Biogas Technology, Working Group on Food Waste Materials, 1981, pp. 52-65.
- [2] Hasan Ahmed and Khalid Md. Bahauddin, International journal of advanced renewable energy research, 2012, Vol. 1, Issue. 6, pp. 313-322.
- [3] BPDB, Bangladesh power development Board, Annual report of 2006-2007, Dhaka, Bangladesh, 2008.
- [4] M.N. Islam, Energy resources and governance issues: Bangladesh perspective, Lecture delivered at policy planning and management Course (PPMC), Organized by Bangladesh public Administration Training Center (BPATC), Savar-1243, Bangladesh, 2012. [5] M. Islam, B. Salam and A. Mohajan, Generation of biogas from anaerobic digestion of vegetable waste, ICME, CUET, Chittagong, Bangladesh, 2009.
- [6] A. Yousuf et. al, Optimization and fabrication of a portable biogas Reactor, journal of Chemical Engineering, IEB, Bangladesh, 2012, Vol. ChE27, No.2, pp.06-10.
- [7] H. Hartmann, I. Angelidaki, B.K. Ahring, Increase of anaerobic degradation of particulate organic matter in full-scale biogas plants by mechanical maceration, Water Science and Technology, 41 (2000) 145-153.
- [8] R.I. Mackie, M.P. Bryant, Anaerobic digestion of cattle waste at mesophilic and thermophilic temperatures, Applied Microbial Biotechnology, 43(1995) 346-350.